

**What Is Claimed Is:**

1           1.       A method for measuring alignment between a first semiconductor  
2 die and a second semiconductor die, comprising:  
3           applying a pattern of voltage signals to a two-dimensional array of  
4 conductive transmitter elements that form a transmitter array on the first  
5 semiconductor die;  
6           wherein the transmitter array on the first semiconductor die is located over  
7 a corresponding two-dimensional array of conductive receiver elements that form  
8 a receiver array on the second semiconductor die;  
9           wherein a voltage signal applied to a transmitter element induces a voltage  
10 signal in one or more receiver elements;  
11           amplifying voltage signals induced in receiver elements in the receiver  
12 array; and  
13           analyzing the amplified signals to determine an alignment between the  
14 first semiconductor die and the second semiconductor die.

1           2.       The method of claim 1, wherein transmitter elements have a  
2 different spacing than receiver elements, whereby a two-dimensional vernier  
3 alignment structure is created when the transmitter array is located over the  
4 receiver array.

1           3.       The method of claim 1,  
2           wherein the transmitter array is organized as a two-dimensional  $n \times m$  grid  
3 including  $nm$  conductive elements; and  
4           wherein the receiver array includes at least three conductive elements  
5 which are not collinear.

1           4.       The method of claim 1,  
2           wherein the receiver array is organized as a two-dimensional  $n \times m$  grid  
3 including  $nm$  conductive elements; and  
4           wherein the transmitter array includes at least three conductive elements  
5 which are not collinear.

1           5.       The method of claim 1, wherein determining the alignment  
2 involves determining six degrees of alignment, including:  
3           an  $x$  alignment parallel to plane of the receiver array;  
4           a  $y$  alignment parallel to plane of the receiver array and normal to the  $x$   
5 axis;  
6           a  $z$  alignment normal to the plane of the receiver array;  
7           an angular alignment,  $\theta$ , about the  $z$  axis;  
8           an angular alignment,  $\Psi$ , about the  $y$  axis; and  
9           an angular alignment,  $\Phi$ , about the  $x$  axis.

1           6.       The method of claim 5, wherein determining the alignment  
2 involves analyzing coupling capacitances between individual receiver elements  
3 and individual transmitter elements to determine the  $x$  alignment, the  $y$  alignment  
4 and the angular alignment,  $\theta$ .

1           7.       The method of claim 6, wherein analyzing the coupling  
2 capacitances involves determining a nearest neighbor mapping between receiver  
3 elements and transmitter elements.

1           8.       The method of claim 5, wherein determining the alignment  
2 involves using a mapping function generated by a three-dimensional capacitance  
3 field solver simulation to determine the z alignment, the angular alignment,  $\Psi$ , and  
4 the angular alignment,  $\Phi$ .

1           9.       The method of claim 5, wherein determining the z alignment, the  
2 angular alignment,  $\Psi$ , and the angular alignment,  $\Phi$ , involves summing  
3 capacitances between individual receiver elements in the receiver array and all  
4 transmitter elements in the transmitter array, thereby effectively considering the  
5 transmitter array to be one large plate.

1           10.      The method of claim 5, wherein determining the z alignment, the  
2 angular alignment,  $\Psi$ , and the angular alignment,  $\Phi$ , involves summing  
3 capacitances between individual transmitter elements in the transmitter array and  
4 all receiver elements in the receiver array, thereby effectively considering the  
5 receiver array to be one large plate.

1           11.      The method of claim 1, further comprising electrically varying the  
2 pitch of the transmitter array by grouping together adjacent transmitter elements.

1           12.      The method of claim 1, further comprising electrically varying the  
2 pitch of the receiver array by grouping together adjacent receiver elements.

1           13.      The method of claim 1, wherein transmitter elements and receiver  
2 elements are:  
3           square;  
4           rectangular;

5 hexagonal;  
6 triangular;  
7 oval; or  
8 round.

1 14. The method of claim 1,  
2 wherein transmitter elements are located in a metal layer of the first  
3 semiconductor die and are not covered by higher layers of metal; and  
4 wherein receiver elements are located in a metal layer of the second  
5 semiconductor die and are not covered by higher layers of metal.

1 15. An apparatus that measures alignment between a first  
2 semiconductor die and a second semiconductor die, comprising:  
3 a two-dimensional array of conductive transmitter elements that form a  
4 transmitter array on the first semiconductor die;  
5 a two-dimensional array of conductive receiver elements that form a  
6 receiver array on the second semiconductor die;  
7 a driving mechanism configured to apply a pattern of voltage signals to the  
8 transmitter array;  
9 wherein a voltage signal applied to a transmitter element induces a voltage  
10 signal in one or more receiver elements when the transmitter array is located over  
11 the receiver array;  
12 an amplification mechanism configured to amplify voltage signals induced  
13 in receiver elements in the receiver array; and  
14 an analysis mechanism configured to analyze the amplified signals to  
15 determine an alignment between the first semiconductor die and the second  
16 semiconductor die.

1           16.     The apparatus of claim 15, wherein transmitter elements have a  
2     different spacing than receiver elements, whereby a two-dimensional vernier  
3     alignment structure is created when the transmitter array is located over the  
4     receiver array.

1           17.     The apparatus of claim 15,  
2             wherein the transmitter array is organized as a two-dimensional  $n \times m$  grid  
3     including  $nm$  conductive elements; and  
4             wherein the receiver array includes at least three conductive elements  
5     which are not collinear.

1           18.     The apparatus of claim 15,  
2             wherein the receiver array is organized as a two-dimensional  $n \times m$  grid  
3     including  $nm$  conductive elements; and  
4             wherein the transmitter array includes at least three conductive elements  
5     which are not collinear.

1           19.     The apparatus of claim 15, wherein the driving mechanism and the  
2     analysis mechanism are configured to determine six degrees of alignment,  
3     including:  
4             an  $x$  alignment parallel to plane of the receiver array;  
5             a  $y$  alignment parallel to plane of the receiver array and normal to the  $x$   
6     axis;  
7             a  $z$  alignment normal to the plane of the receiver array;  
8             an angular alignment,  $\theta$ , about the  $z$  axis;  
9             an angular alignment,  $\Psi$ , about the  $y$  axis; and

1 an angular alignment,  $\Phi$ , about the  $x$  axis.

1 20. The apparatus of claim 19, wherein the analysis mechanism is  
2 configured to determine coupling capacitances between individual receiver  
3 elements and individual transmitter elements to determine the  $x$  alignment, the  $y$   
4 alignment and the angular alignment,  $\theta$ .

1 21. The apparatus of claim 20, wherein the analysis mechanism is  
2 configured to determine a nearest neighbor mapping between receiver elements  
3 and transmitter elements.

1 22. The apparatus of claim 19, wherein the analysis mechanism is  
2 configured to use a mapping function generated by a three-dimensional  
3 capacitance field solver simulation to determine the  $z$  alignment, the angular  
4 alignment,  $\Psi$ , and the angular alignment,  $\Phi$ .

1 23. The apparatus of claim 19, wherein the apparatus is configured to  
2 determine the  $z$  alignment, the angular alignment,  $\Psi$ , and the angular alignment,  
3  $\Phi$ , by summing capacitances between individual receiver elements in the receiver  
4 array and all transmitter elements in the transmitter array, thereby effectively  
5 considering the transmitter array to be one large plate.

1 24. The apparatus of claim 19, wherein the apparatus is configured to  
2 determine the  $z$  alignment, the angular alignment,  $\Psi$ , and the angular alignment,  
3  $\Phi$ , by summing capacitances between individual transmitter elements in the  
4 transmitter array and all receiver elements in the receiver array, thereby effectively  
5 considering the receiver array to be one large plate.

1           25.     The apparatus of claim 15, wherein the apparatus is configured to  
2 electrically vary the pitch of the transmitter array by grouping together adjacent  
3 transmitter elements.

1           26.     The apparatus of claim 15, wherein the apparatus is configured to  
2 electrically vary the pitch of the receiver array by grouping together adjacent  
3 receiver elements.

1           27.     The apparatus of claim 15, wherein transmitter elements and  
2 receiver elements are:  
3           square;  
4           rectangular;  
5           hexagonal;  
6           triangular;  
7           oval; or  
8           round.

1           28.     The apparatus of claim 15,  
2           wherein transmitter elements are located in a metal layer of the first  
3 semiconductor die and are not covered by higher layers of metal; and  
4           wherein receiver elements are located in a metal layer of the second  
5 semiconductor die and are not covered by higher layers of metal.